# MITIGATION OF CM CONDUCTED EMI IN SMPS

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***Abstract*—The offline SMPS are efficient, lightweight widely used converters in consumer electronics connected to utility mains. Because of high- frequency switching, they produce conducted and radiated EMI also offering low power factor to the utility mains. The two issues involved in the SMPS are to increase the Power Factor and to mitigate the EMI, to comply with EMC standards. Techniques for reducing the conducted EMI for offline SMPS and NUPF have been developed. A design procedure has been adopted for line filter and it has been tested on commercially available offline SMPS and on NUPF which was designed and fabricated. Experimentation and simulation are carried out with and without EMI line filter for a 30W flyback NUPF and a significant reduction in CM conducted EMI is presented. Advances in computer-aided design software and device models have enabled the simulation of NUPF converter and to obtain accurate waveforms. Simulation result obtained are in close agreement with experimental results.**

***Keywords*—EMI, LISN, NUPF converter, Differential Mode(DM), Common Mode(CM), Flyback converter.**

## I. Introduction

The Switched Mode Power Supplies (SMPS) are efficient, lightweight and are widely used in computers and in consumer electronic appliances which draw power from the single phase public utility lines. But these SMPS switch at very high frequency and pollute the mains by generating Electromagnetic Interference (EMI) hence causing compatibility issues and offer low power factor to the utility mains. Therefore, it is necessary to improve their power factor and mitigate the EMI to meet the electromagnetic compatibility (EMC) standards. The near unity power factor (N.U.P.F) converters are used to improve the power factor offered by the SMPS. However, such converters generate high conducted and radiated EMI [1,2].

This paper addresses EMI compatibility issues for both SMPS and NUPF converter. The conducted EMI can be categorized into a differential mode (DM) conducted EMI and common mode (CM) conducted EMI [3]. This paper addresses reduction of CM conducted EMI in the SMPS and N.U.P.F converter. The design procedure for line filter is presented. The NUPF converter used here utilizes the commercially available control IC L6561[2,3]. The main issue related to SMPS is the increased EMI. The CM noise mitigation in both SMPS and NUPF can be achieved by line filter. A simple design procedure which can mitigate conducted EMI in both types of converters over a frequency range of 1MHz to 30MHz is presented here. The conducted emission is mitigated using EMI line filter. The CM conducted EMI is mainly due to the capacitive coupling of switching element, diodes, inductors, a heat sink to ground which varies from the converter to converter depending on the topology and placement of components. The parasitics of components also plays an important role. However, the parasitics can be measured and used in design and simulation.

A commercially available offline flyback SMPS and practically designed NUPF converter of same wattage and topology are tested for Conducted EMI. The conducted CM and DM EMI were experimentally determined for the offline SMPS and the line filter to mitigate the CM EMI from the frequency range of 1MHz to 30MHz was designed. The line filter was incorporated and the experiments were conducted, it was found that CM noise in that frequency range was considerably reduced. Hence the line filter design presented here mitigates CM noise considerably for both the types of SMPS (i.e flyback and NUPF).

The NUPF converter here was simulated for CM conducted EMI emission using LTspice software and was tested practically.Significant reduction of CM conducted EMI was found after the incorporation of EMI line filter. The power factor is increased which has been measured. Also, the simulation results of CM conducted EMI measured before and after incorporation of the EMI line filter are presented. The simulation validates the procedure adopted in the design and calculation of low conducted EMI in N.U.P.F converter.

## II. NUPF Converter Circuit Design

Power factor correction (PFC) circuit provides near unity power factor and low harmonics, is located at front end of the SMPS. The high power factor exhibited in this topology [4, 5] Fig.1, meets a P.F greater than 0.9. In Fig.1 first block is Line Impedance Stabilization Network (LISN) followed by CM EMI Line Filter detailed in the section IV. The diode bridge rectifies the input voltage which is followed by PFC controller L6561. This controller has two feedbacks, primarily it makes the input current sinusoidal and improving the power factor and it regulates the output voltage.

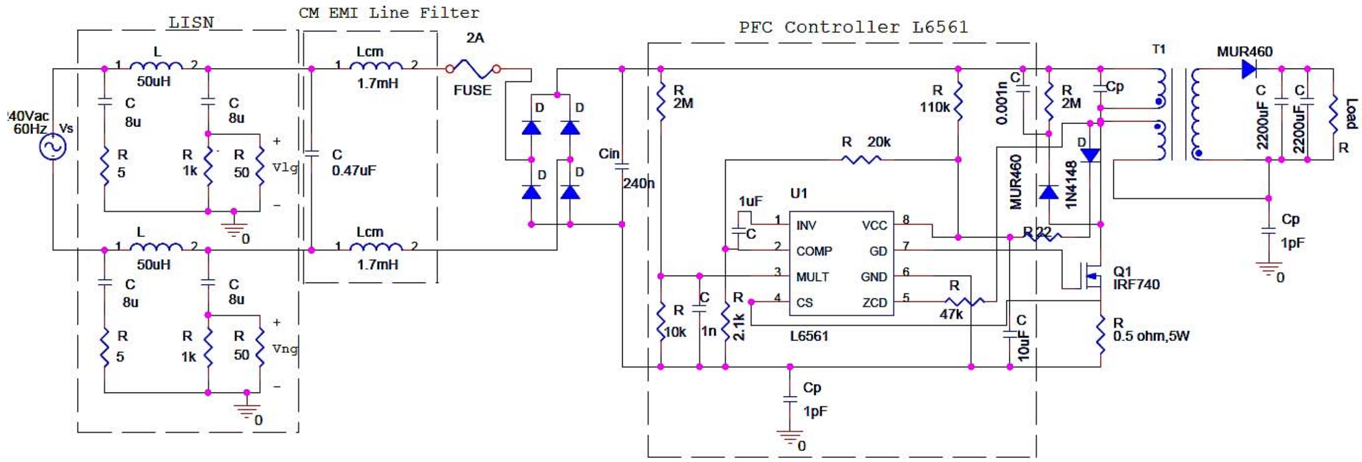


Fig. 1. Design and simulation circuit of NUPF

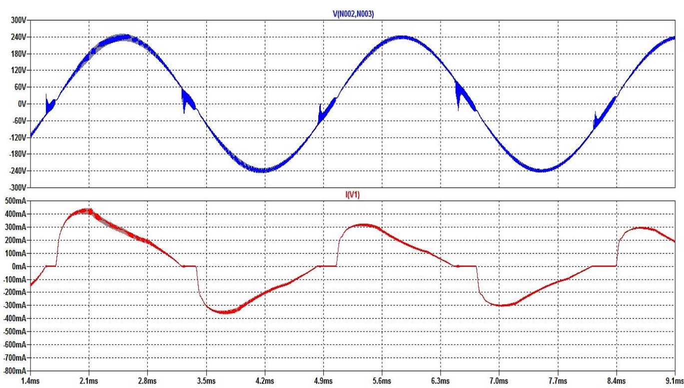


Fig. 2. Input voltage and input current of NUPF converter.

A 30W offline flyback configuration NUPF ensures high power factor. In this NUPF a large electrolytic capacitor at the output terminal is used to reduce the output ripple [5]. Although NUPF usually uses a smaller electrolytic capacitor, a larger capacitor is used here for stringent reduction in ripple voltage. This also offers a good transient suppression which frequently occurs on utility mains [6]. It is a challenge to meet the EMI standards at low power range. There are several applications in the low power range that are advantageous such as:

- The input capacitor is smaller in size when compared to bulky and high voltage electrolytic capacitors in SMPS.
- Efficiency is high.
- Low parts count and low-cost design.

The NUPF correction SMPS circuit specifications [7] are as listed in Table I

The simulation results of the proposed topology are shown in fig 2. In this, the input current and voltage waveforms are in phase providing the power factor correction of 0.9 as obtained from simulation result. As this converter produces high EMI, the EMI line filter was designed to mitigate CM Conducted EMI which is explained in next section.

TABLE I
NUPF CONVERTER DESIGN SPECIFICATIONS

| | |
|---|---|
| Mains voltage range | VACmin= 88Vac, VACmax =264V |
| DC output voltage | 15V |
| Maximum output current | 2A |
| Minimum switching frequency | 25 KHz |
| Total Efficiency | 85% |
| Peak primary current | 2.12A |
| Peak secondary current | 13A |
| Power factor | 0.9 |

## III. COMMERCIALLY AVAILABLE FLYBACK SMPS

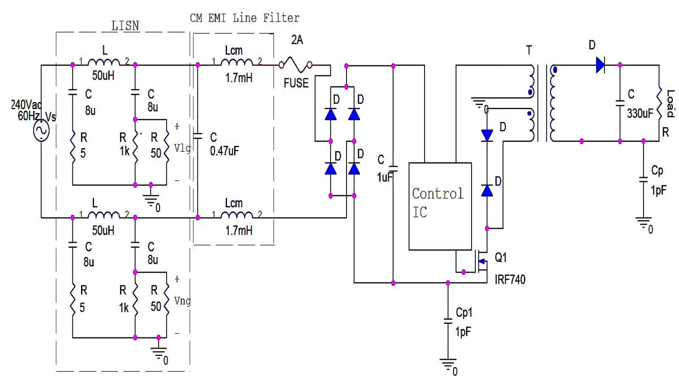


Fig. 3. Comercially available SMPS

In Fig.3 first block is Line Impedance Stabilization Network (LISN) followed by CM EMI Line Filter detailed in section IV. The commercially available Flyback SMPS was experimentally tested for CM and DM conducted EMI which are presented in Fig.4 and Fig.5. The flyback SMPS circuit specifications is as listed in Table II.

For this SMPS the line filter was designed in the same way as explained in section IV. So designed EMI filter was incorporated and experiments were conducted and the EMI for CM and DM mode were measured which has been presented

TABLE II
FLYBACK SMPS DESIGN SPECIFICATIONS

| | |
|---|---|
| Mains voltage range | VACmin= 88Vac, VACmax =264V |
| DC output voltage | 15V |
| Maximum output current | 2A |
| Minimum switching frequency | 50 KHz |
| Total Efficiency | 85% |

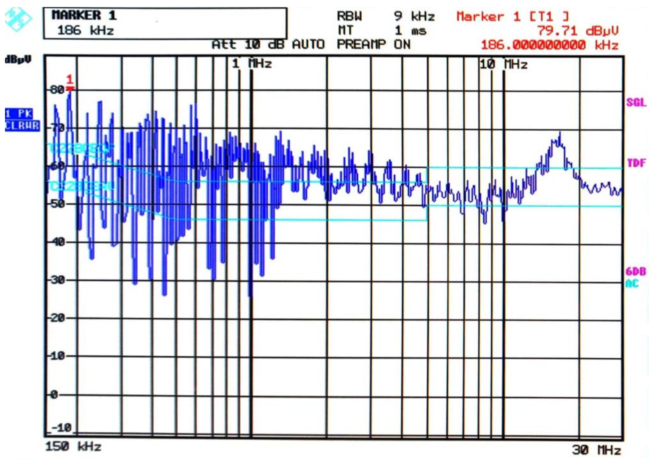


Fig. 4. Experimental plot of Line to Ground Conducted EMI of SMPS

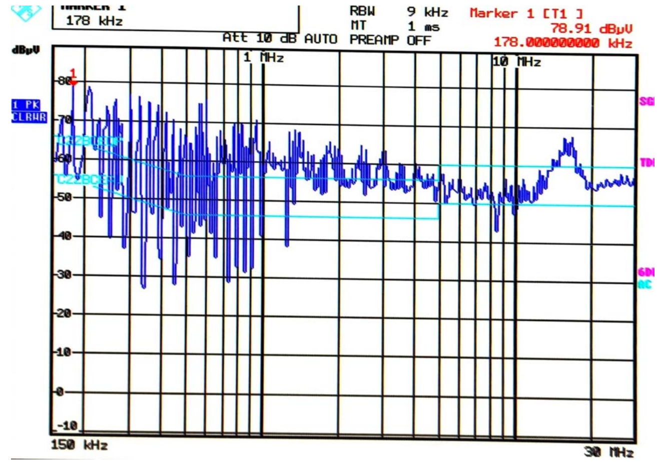


Fig. 5. Experimental plot of Neutral to Ground Conducted EMI of SMPS

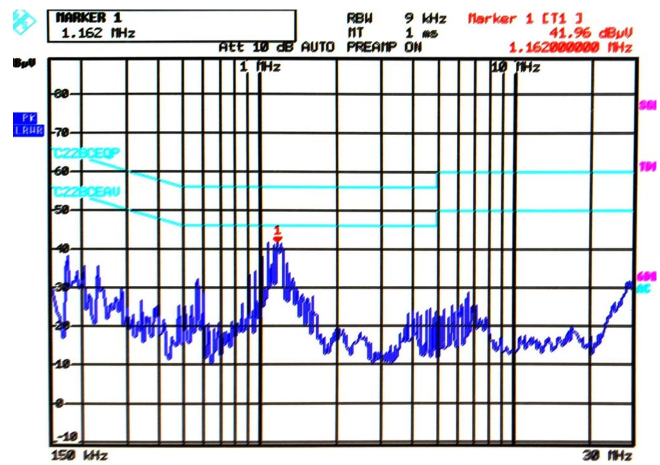


Fig. 6. Experimental plot of Line to Ground Conducted EMI with filter for SMPS

in the Fig.6 and Fig.7. It is evidenced in these figures that the line filter has reduced CM noise in the frequency range 1MHz to 30MHz.

## IV. EMI FILTER DESIGN

EMI in converter induces unwanted noise signals into the electronic systems, including the SMPS supplementary circuits. It is possible to filter out the unwanted noise signals without affecting the performance of the converter. EMI line filter designing is a crucial part for SMPS to be compliance with EMI standards. The EMI line filter is designed to attenuate high-frequency noise without affecting the desired signal.

The CISPR 22 Class B conducted emission requires Line Impedance Stabilization Network (LISN). EMI standards have specified a standard network, called LISN for conducted EMI measurement in the frequency range of 150 kHz to 30MHz [8]. The conducted EMI is measured at the 50Ω terminal of Rohde & Schwarz EMI receiver. The noise was measured between the line to ground (Vlg) and neutral to ground(Vng). The CM and DM conducted EMI were calculated. Measured noise across Vlg and Vng in line and neutral terminals of the LISN with respect to ground is depicted in Fig.1. The experimental measurements and simulation results across the Vlg and Vng data of x and y-axis is taken to excel sheet and are plotted as shown in Fig.8 and Fig.9 for NUPF converter. For SMPS the experimental measurement across Line to ground is as shown in Fig.4 and for Neutral to ground is as shown in Fig.5.

### A. EMI filter calculations

Some of the EMI line filter designed is effective and simple in mitigating of Conducted EMI [9-13] The EMI filter design procedure followed from [14,15] steps are listed as follows:

- The N.U.P.F converter designed above CM and DM noise levels are measured (in dB$\mu$V) in the frequency range of 150 kHz to 30MHz. EMI noise estimation delivers a voltage drop $V_d$. and "n" is the odd harmonics, therefore, EMI amplitude An can be determined.
- Determine the required filter attenuation considering an additional safety margin m to keep the EMI noise below the limits

$$A[dB\mu V] = A_n - L_{QP} + m \tag{1}$$

$A_n$ EMI amplitude of the nth harmonic (first harmonic above 150 kHz)
$L_{QP}$ EMI Quasi-Peak limit at the nth harmonic (first harmonic above 150 kHz)
m safety margin (e.g. 3dB)

- The filter corner frequency should be determined.

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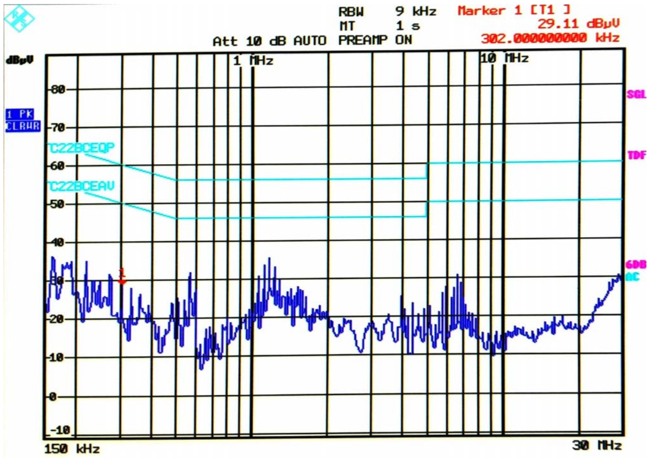


Fig. 7. Experimental plot of Neutral to Ground Conducted EMI of SMPS

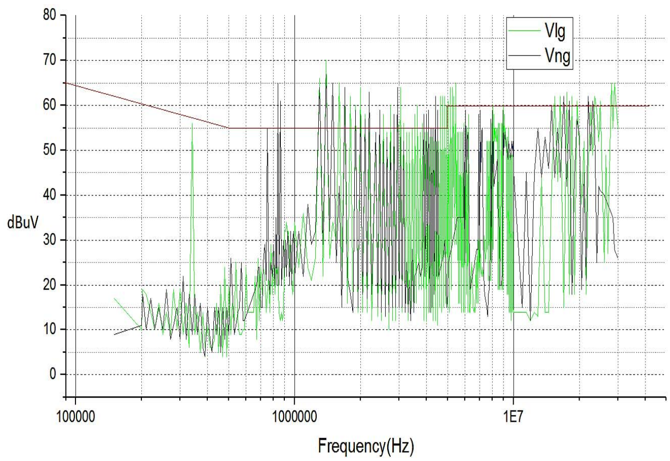


Fig. 8. Experimental plot of Line and Neutral Conducted EMI without line filter of NUPF converter

$$A[dB\mu V] = 40log\frac{f}{f_c} \tag{2}$$

$f_c = 10^{\frac{-A}{40}} f$

- Selection of Inductor ($L_{cm}$) and Capacitor ($C_y$).

First order CM filter

$$f_c\ of\ CM = \frac{1}{50\pi C_y} \tag{3}$$

Second order CM filter

$$f_c\ of\ CM = \frac{1}{2\pi\sqrt{2L_{cm}C_y}} \tag{4}$$

For NUPF converter the line filter values are as follows, Lcm was calculated to be 1.7mH and a capacitance $C_x$ of 0.47$\mu$F,$C_y$ of 470pF. The other component values of line filter were used as per standards. The topology of line filter is presented in Fig.10 is used for flyback SMPS and NUPF is presented here, only $L_{cm}$ and $C_y$ capacitor has been used in the design. Common mode line choke of 1.7mH (P3214-AL) from [16] is used as $L_{cm}$. For SMPS, EMI line filter value is calculated using the above analytical method.

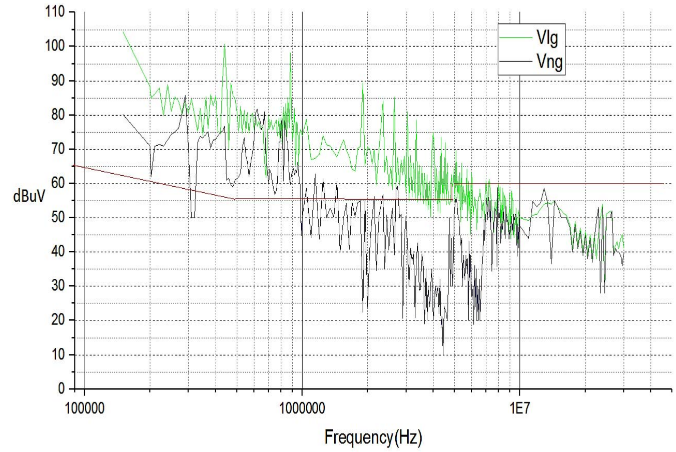


Fig. 9. Simulated plot of Line and Neutral Conducted EMI without line filter for NUPF converter

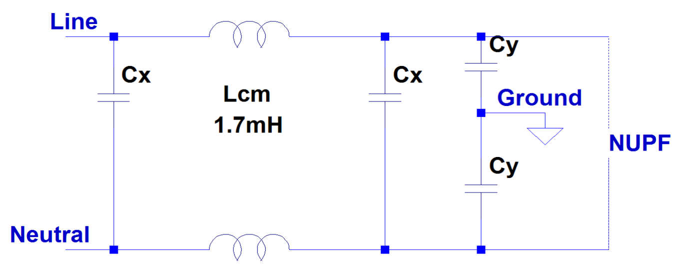


Fig. 10. Experimental plot of Neutral to Ground Conducted EMI of SMPS

The same topology line filter has been used for SMPS and NUPF. The values of the parasitic have been measured for NUPF converter, the primary side of the inductor using LCR bridge HM8118 [17]. The $C_p$ from Fig. 1, measured is about 30pF. These filters were incorporated and the noise was measured experimentally and was found to be in the specified international limits. This experimentation validates the CM EMI line filter from 1MHz to 30MHz.

### B. EMI measurement

In NUPF converter, analytical calculation determines the CM inductance and capacitance to reduce the CM conducted EMI and the parasitic is extracted from the LCR bridge. These measurements are put into the simulation as in Fig.1. The simulation result with and without filter is superimposed with the practical results as shown in Fig.11 and Fig.12. The measurement result is presented in Fig.13 and Fig.14, practical testing was done in ETDC [18]. It is showing a good compliance from 1MHz to 30MHz.

## V. Conclusion

A simplified line filter designed for reducing CM conducted noise in offline SMPS and NUPF converter is presented here. This was tested and simulated for 30W, 15Vdc NUPF

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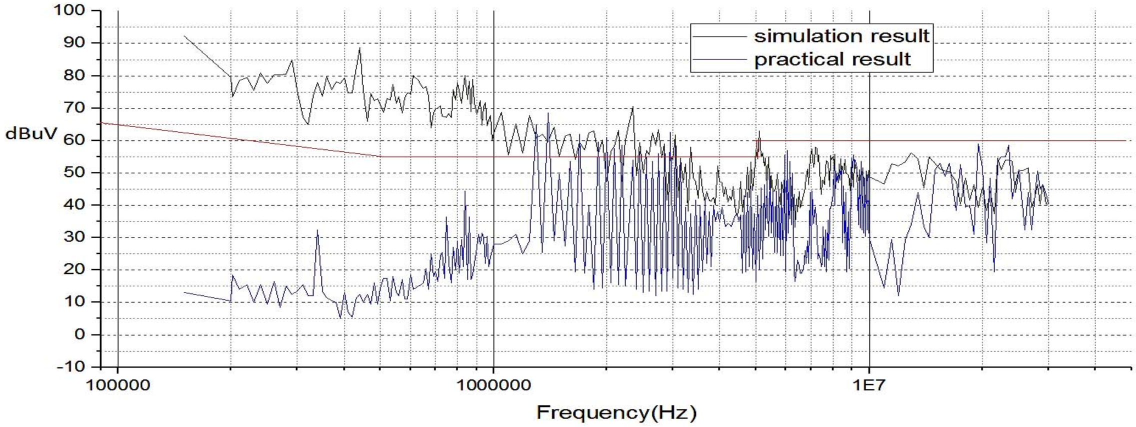


Fig. 11. Experimental and Simulated CM Conducted EMI plot without filter for NUPF converter

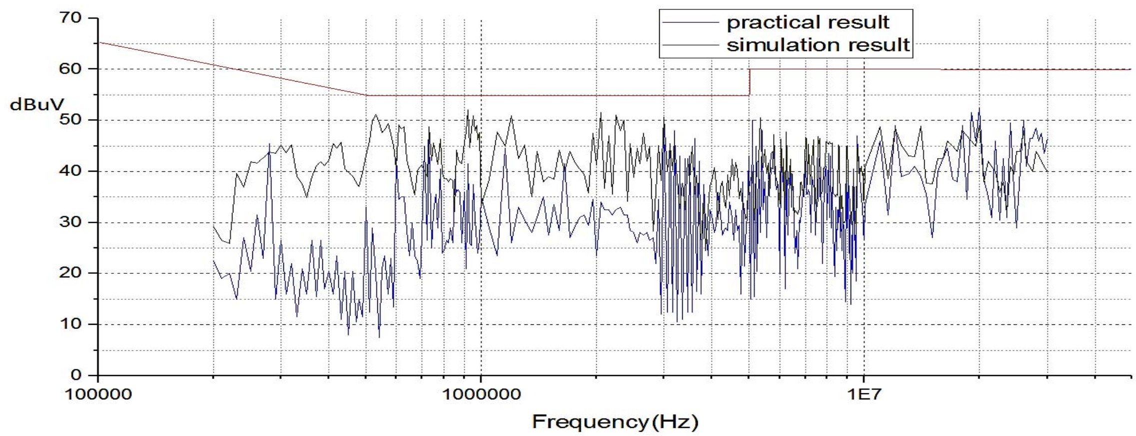


Fig. 12. Experimental and Simulated CM Conducted EMI plot with filter for NUPF converter

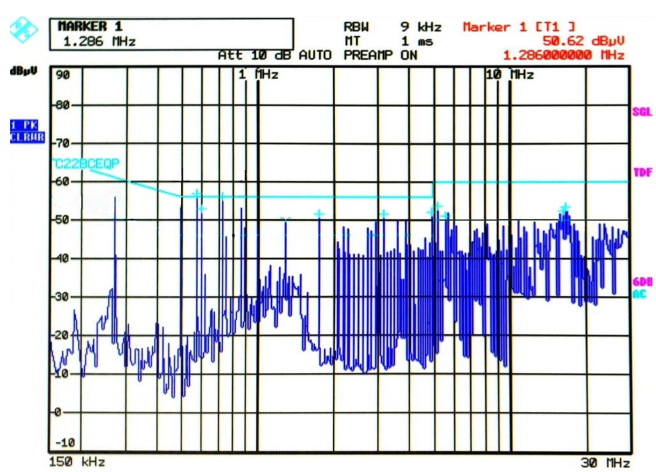


Fig. 13. Experimental plot of Neutral to Ground Conducted EMI of SMPS

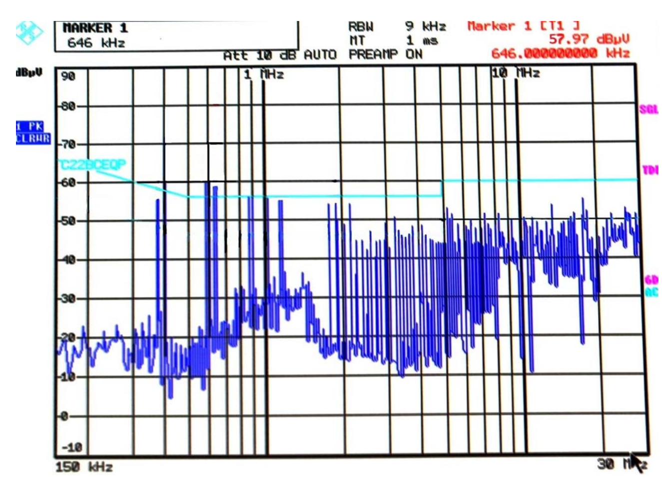


Fig. 14. Experimental plot of Neutral to Ground Conducted EMI of SMPS

converter and for a commercially available offline flyback SMPS. Both these converters were tested without line filter and the generated conducted EMI noise has been presented. The line filter was designed and are incorporated into the circuit. The noise was experimentally obtained after incorporating of the filter for both the converters. The experimental result with and without a filter for mitigation of CM conducted EMI in the frequency range of 1MHz to 30MHz validates the design procedure.

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